Nucleation of Continuous, Conformal and Smooth Ultrananocrystalline Diamond (UNCD) Thin Films

Scientific Achievement

Optimization of the properties of ultrananocrystalline diamond (UNCD) thin films have generally been carried out via control of gas chemistry, growth temperature and growth templates. However, seeding has been found to be the most crucial step for depositing successful conformal, continuous and smooth UNCD films. UNCD is commonly grown on refractory metal substrates in order to integrate the growth of UNCD with a standardized process for generating a high initial nucleation density that is also compatible with low temperature growth of UNCD. In this study, we apply thin tungsten (W) films onto silicon surfaces prior to ultrasonic seeding. The thickness of the W layers varies from 36 Å to 100 Å. We have found that the initial UNCD nucleation density is enhanced considerably using W films from 10^{11} to $\geq 10^{12}$ sites/cm^2, resulting in lower surface roughness and interfacial void density. Furthermore, by using W films and obtaining this high initial nucleation density, less time is needed to grow a uniform UNCD film and thus extremely thin diamond films can be realized.

Significance

The initial nucleation density is critical in determining the properties of Ultrananocrystalline Diamond (UNCD) films. Unlike hydrogen grown diamond thin films, the UNCD growth process results in a high re-nucleation rate, and thus the overall grain size is not limited by the initial nucleation density. However, a low nucleation density can lead to the formation of voids at the film-substrate interface, drastically affecting the bulk mechanical and electronic properties of the film. Thus, controlling the nucleation density is critical in determining the quality of UNCD thin films, especially for facilitating the growth of low-temperature UNCD thin films and maximizing the mechanical and tribological properties of UNCD for potential MEMS and bio-applications.

This work highlights the importance of seeding on both film structure and the surface chemistry of UNCD. This will ultimately influence the mechanical properties especially tribological properties of this material. The capability to control the surface chemistry and the surface roughness of UNCD provides a novel approach to fabricate unique UNCD films. This research will open some fundamental questions about the seeding processes and initial growth stages of diamond films. This work will be submitted to the journal *Advanced Materials* for publication as a research news article.

Performers

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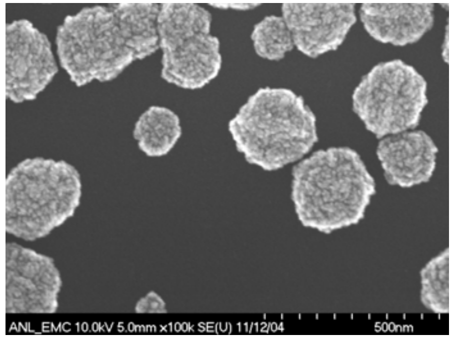
UNCD Potential Application:

- MEMS
- Bio-applications

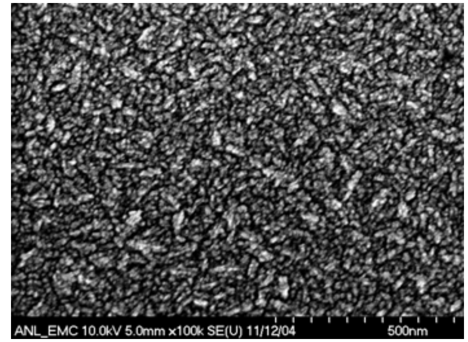
UNCD must be:

- Continuous
- Conformal
- Smooth



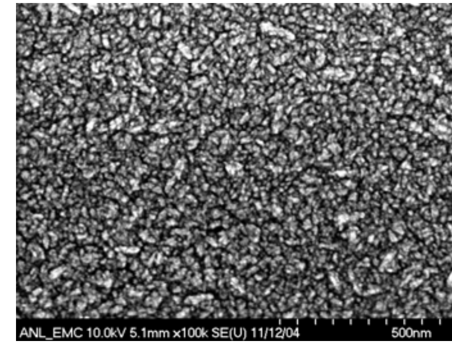
UNCD on plain Si

(no W)



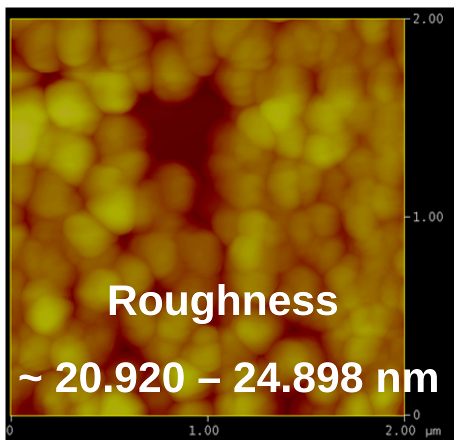
UNCD on Sputtered W

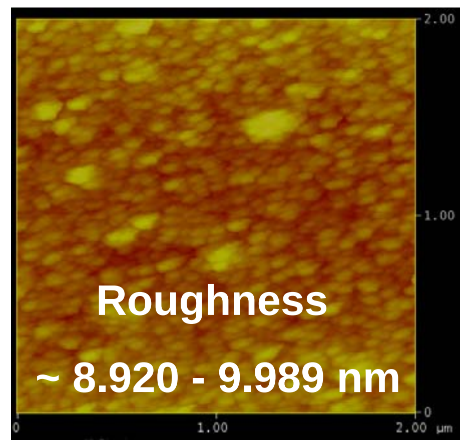
(~105Å W thickness)

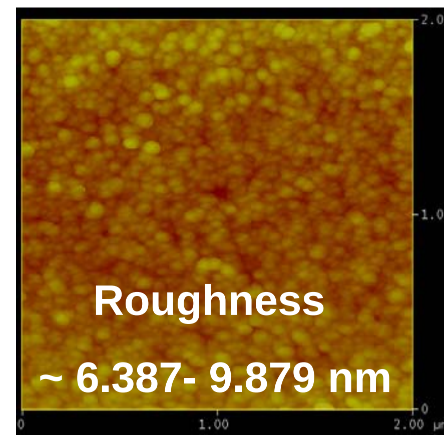


UNCD on ALD W

(~100Å W thickness)







Tungsten is used as a seed layer to enhance the initial nucleation and thus decrease roughness and improve conformality.

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